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INT CL^5 H04B 7/212 7/26
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(54) Timing of transmission from a mobile unit in a TDMA communications system

(57) A communications system comprises a base station (10) and a mobile radio (11) arranged for communication over a TDMA channel having a predetermined frame reference. The base station receives signals from the mobile radio, measures the timing of those signals relative to the frame reference and transmits a timing advance signal to the mobile radio. The mobile radio receives the timing advance signal, and by means of control circuitry (28) adjusts the timing of transmissions in response to the received timing advance signal. The mobile radio has means (26, 25) for estimating change of distance from the base station since last receiving a timing advance signal and for requesting a new timing advance signal from the base station if it is decided one is required.

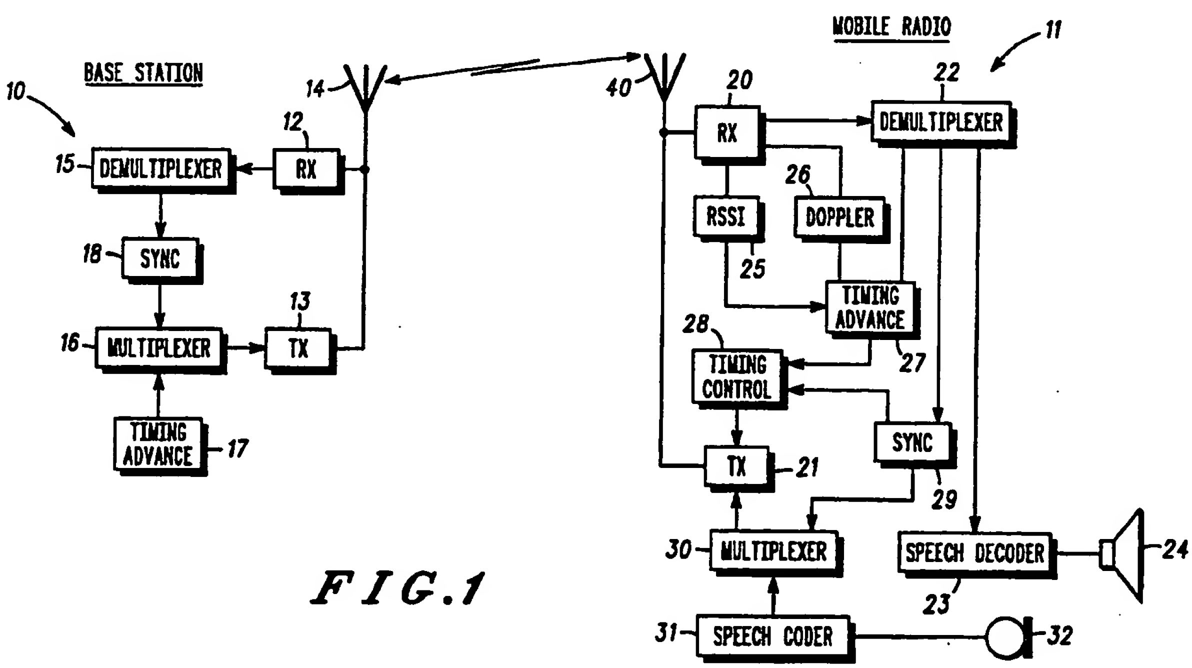

FIG.1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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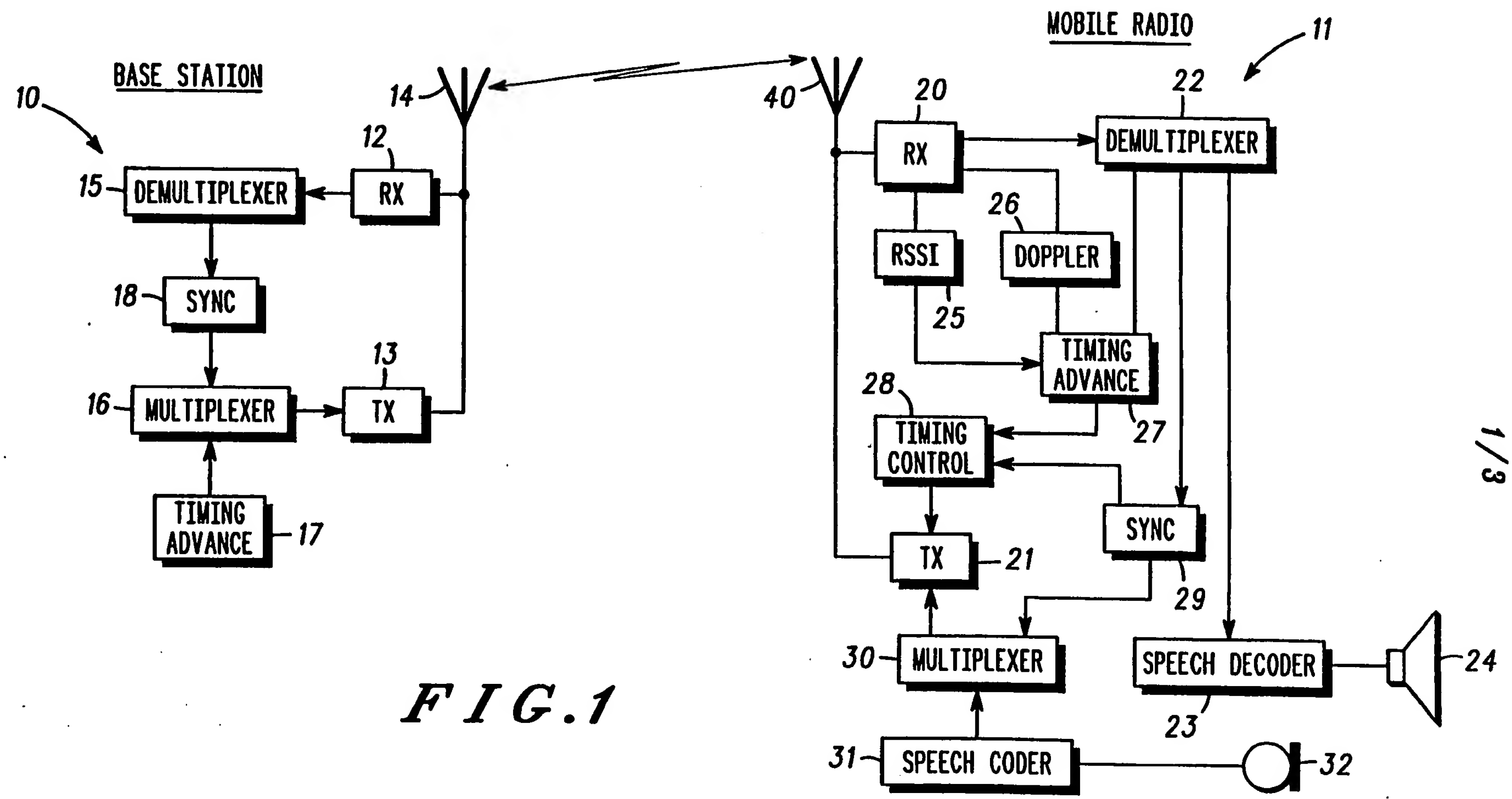

BASE STATION
10
14
12
15
DEMULTIPLEXER
RX
18
SYNC
13
16
MULTIPLEXER
TX
TIMING ADVANCE
17
MOBILE RADIO
11
40
20
22
RX
DEMULTIPLEXER
26
RSSI
DOPPLER
25
TIMING ADVANCE
28
27
TIMING CONTROL
SYNC
TX
21
29
30
MULTIPLEXER
SPEECH DECODER
24
23
31
SPEECH CODER
32

FIG.1

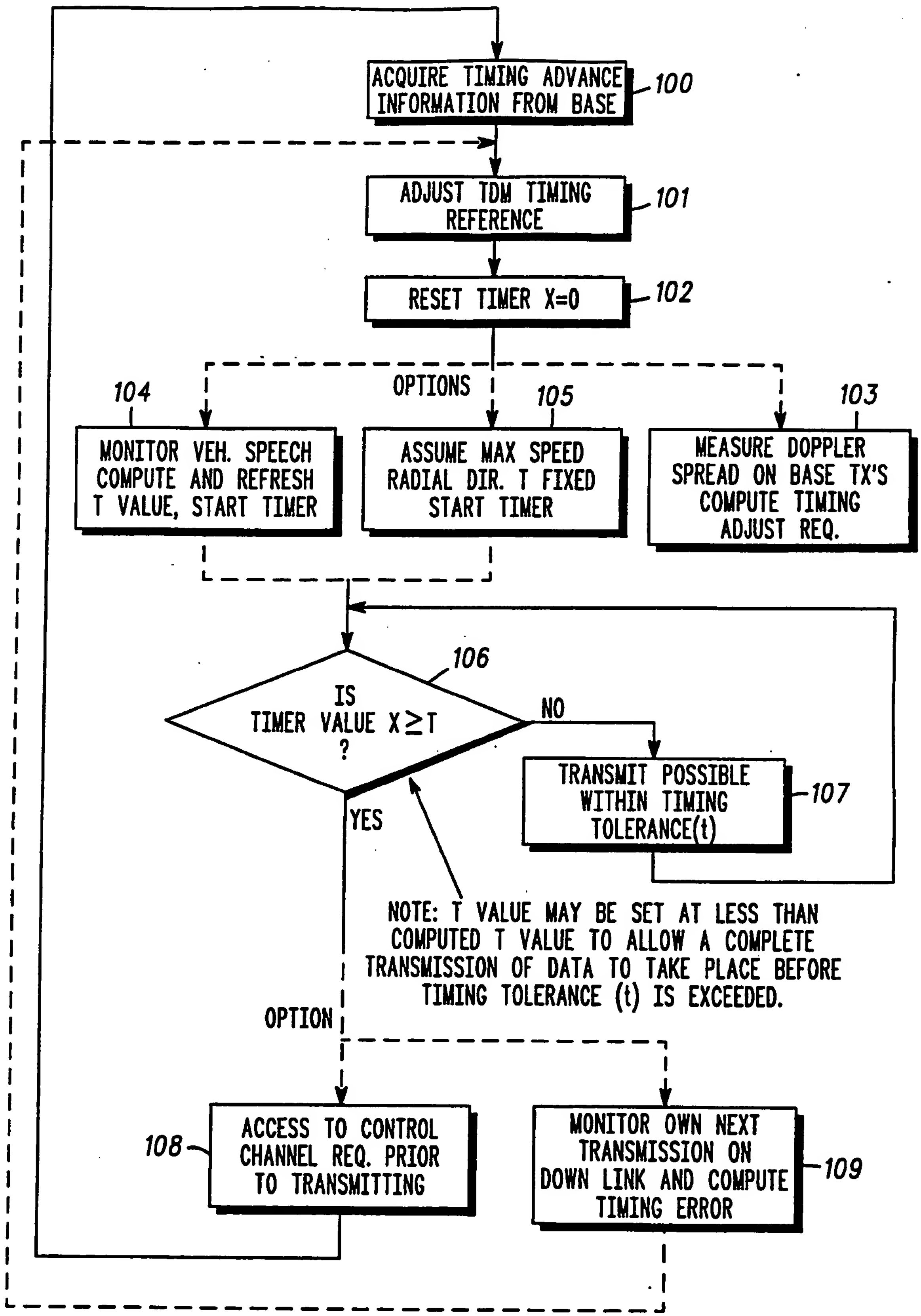

ACQUIRE TIMING ADVANCE INFORMATION FROM BASE
100
ADJUST TDM TIMING REFERENCE
101
RESET TIMER X=0
102
OPTIONS
104
MONITOR VEH. SPEECH COMPUTE AND REFRESH T VALUE, START TIMER
105
ASSUME MAX SPEED RADIAL DIR. T FIXED START TIMER
103
MEASURE DOPPLER SPREAD ON BASE TX'S COMPUTE TIMING ADJUST REQ.
106
IS TIMER VALUE X≥T ?
NO
TRANSMIT POSSIBLE WITHIN TIMING TOLERANCE(t)
107
YES
NOTE: T VALUE MAY BE SET AT LESS THAN COMPUTED T VALUE TO ALLOW A COMPLETE TRANSMISSION OF DATA TO TAKE PLACE BEFORE TIMING TOLERANCE (t) IS EXCEEDED.
OPTION
108
ACCESS TO CONTROL CHANNEL REQ. PRIOR TO TRANSMITTING
MONITOR OWN NEXT TRANSMISSION ON DOWN LINK AND COMPUTE TIMING ERROR
109

FIG.2

FIG.3

—PRIOR ART—

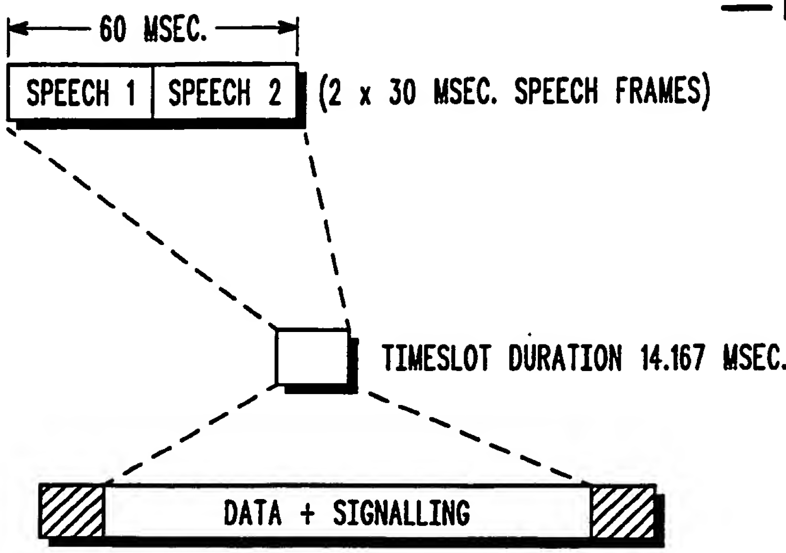
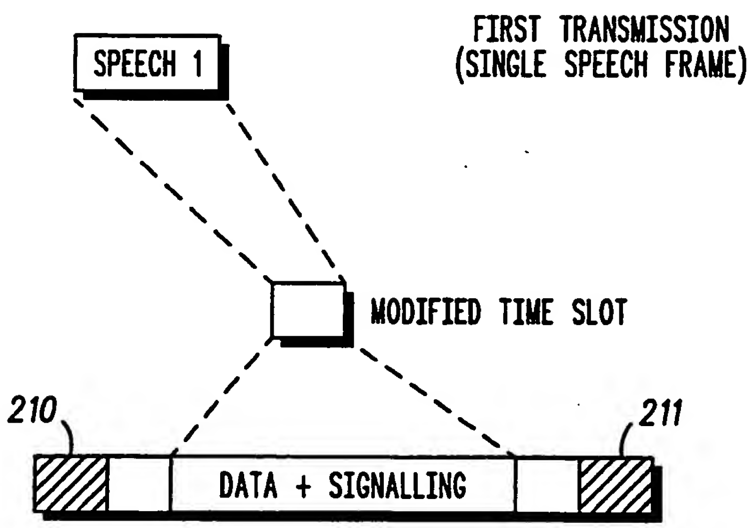


FIG.4



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A COMMUNICATIONS SYSTEM AND A MOBILE RADIO

Field of the Invention

This invention relates to a communications system comprising a base station and a mobile radio arranged for communication over a TDMA channel. The invention additionally and separately relates to a mobile radio of such a communications system.

Summary of the Prior Art

It is known to provide a communications system, such as the Pan-European digital cellular telephone system known as "GSM", which comprises a base station and a mobile radio arranged for communication over a TDMA channel. The base station has means for receiving signals from the mobile radio, means for measuring the timing of those signals relative to a frame reference and means for transmitting a timing advance signal to the mobile radio for instructing the mobile radio to adjust the timing of its transmissions. The mobile radio in addition comprises means for receiving the timing advance signal and adjusting the timing of subsequent transmissions accordingly, either by advancing or retarding those transmission.

In this way, the arrival time of a burst from a mobile radio is controlled to be in synchronization when arriving at the base station, independent of the distance between the radio unit and the base station.

The known arrangements give rise to problems when translated to a private mobile radio system, such as the proposed new digital European trunking system known as TETRA.

A problem in a private mobile radio system is that the signalling resource is particularly valuable and signalling information should be kept to a minimum. A further problem is that a user frequently wishes to immediately have access to a channel with the minimum of delay.

The exchange of information between a mobile radio and the base station, by which the base station measures the

timing of the mobile radio and reports this back to the mobile radio, is generally performed on a control channel (either a dedicated control channel or a temporarily allocated control channel). It can be undesirable to have every transmission in a two-way simplex/half duplex message requiring an access request on a control channel.

In the proposed TETRA system, each time slot can typically carry two speech frames. The first two speech frames are in effect unusable when a new call is established and the mobile radio and the base station are establishing the necessary accurate timing. This represents a delay in transmitting speech and also represents a waste of traffic capacity.

There is a need for improved establishment of timing information in a TDMA communications system and of call set up.

Summary of the Invention

In accordance with the first aspect of the present invention, a mobile radio is provided which is arranged to estimate change of distance from the base station since last receiving a timing advance signal and locally to decide whether transmit timing adjustment is required.

In one embodiment, the mobile radio is arranged to request a new timing advance signal at a time which is dependent on said estimated change of distance.

The means for estimating change of distance may, for example, comprise Doppler shift measurement means for estimating speed relative to the base station and integrator means for integrating said speed over time.

Alternatively, or in addition, the means for estimating change of distance may comprise means for transmitting at a predetermined power known to the mobile radio and means for measuring the attenuation from said known power of transmissions received from the base station.

In this manner, new requests for timing advance signals and new transmissions of timing advance signals are sent no more frequently than necessary for the unit in question.

In accordance with a second embodiment of the invention, the mobile radio comprises means for independently adjusting the timing of subsequent transmissions when the mobile radio locally decides that timing adjustment is required.

In this manner, a mobile radio can "track" its required timing advance even though it is moving relative to the base station. The timing advance can be tracked without a mobile having to send a signal to the base station and receive a timing advance signal in return. Thus, there is no additional utilization of the signalling resource.

A further or alternative arrangement could be provided by the base station periodically transmitting an accurate time signal and the mobile radio receiving this time signal and comparing it with an accurate clock local to the mobile radio. If the mobile radio detects a change, it can deduce that this is due to a change in propagation delay. A sufficiently accurate clock could be provided by a global positioning system (GPS) receiver, though this is not entirely necessary since accuracy need only be maintained over short periods and a simple quartz clock can suffice. Instead of a time signal, a regular (e.g. broadcast) synchronization signal from the base station can be used, in which case the mobile radio measures the relative time between anticipated receipt of a synchronisation signal and actual receipt.

In another aspect of the invention, a communications system is provided comprising a base station and a mobile radio arranged for communication over a TDMA channel having a predetermined frame reference, said channel being divided into time slots, wherein the base station comprises means for receiving signals from the mobile radio, means for measuring the timing of those signals relative to said frame reference and means for transmitting a timing advance signal to the mobile radio and wherein the mobile radio comprises means for receiving the timing advance signal, means for transmitting traffic to the base station in bursts of a predetermined duration and means for adjusting the timing of transmitting of its bursts in response to the timing advance signal, characterized in that the mobile radio comprises means for

transmitting a burst of reduced duration, less than said predetermined duration, and means for receiving a timing advance signal in response to transmission of said burst of reduced duration so as to enable commencement of transmission of bursts of said predetermined duration with adjusted timing.

The mobile radio may comprise a speech coder for coding speech in frames of encoded speech and means for compiling said bursts from said frames of encoded speech where each burst of said predetermined duration comprises N frames of encoded speech and said burst of reduced duration comprises M frames of encoded speech, where N and M are non-zero integers and M is less than N.

In this way, although the first time slot comprises N-M fewer speech frames than subsequent time slots, the remaining M frames are still used for sending encoded speech. Thus transmission of speech commences at the earliest time and the M frames are not wasted. In a preferred arrangement, N = 2 and M = 1.

As well as a communications system, the invention relates to a mobile radio *per se*.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the figures.

Brief Description of the Drawings

Fig. 1 shows a base station and a mobile radio in accordance with the preferred embodiment of the invention.

Fig. 2 shows a flow diagram of operation of elements of Fig. 1.

Fig. 3 shows a prior art TDMA protocol and

Fig. 4 shows a TDMA protocol modified in accordance with the preferred embodiment of the invention.

Referring to Fig. 1, there is shown on the left-hand side of the figure a base station 10 and on the right-hand side a mobile radio 11.

The base station 10 comprises a receiver 12 and a transmitter 13 coupled to an antenna 14. Demultiplexer

circuitry 15 is coupled to the receiver 12 and to synchronization circuitry 18. Coupled to the transmitter 13 is multiplexer circuitry 16, timing advance circuitry 17 and synchronization circuitry 18. Coded speech or data is input to the multiplexer 16 and output from the demultiplexer 15, but this circuitry is not shown, as its structure and operation is well known to one skilled in the art.

The mobile radio 11 comprises receiver circuitry 20 and transmitter circuitry 21. Coupled to the receiver circuitry 20 is a demultiplexer 22 which is in turn connected to a speech decoder 23 for decoding speech signals and eventually outputting speech at a loudspeaker 24. Also connected to the receiver 20 is a receive strength indicator circuit (RSSI) 25 and a Doppler shift measurement circuit 26. Also shown are timing advance circuitry 27, timing control circuitry 28 and synchronization circuitry 29.

Coupled to the transmitter 21 is a multiplexer 30 having a speech coder 31 connected thereto, for coding of speech input at a microphone 32.

Operation of the apparatus is as follows. The base station periodically transmits synchronization words generated at synchronization circuitry 18 and multiplexed onto the TDMA channel by multiplexer 16 and transmitted by transmitter 13 through antenna 14. These synchronization words are subject to propagation delay over the radio channels and, when received at receiver 20 via antenna 40 and demultiplexed by demultiplexer 22, the synchronization words are input to synchronization circuitry 29 in the mobile radio 11. On their own, these synchronization words do not tell the mobile radio its distance from the base station.

When the mobile radio 11 wishes to transmit, it inputs a request for channel grant from signalling circuitry (not shown) into the multiplexer 30 and this request is transmitted by transmitter 21. At the same time, a synchronization word is input to the multiplexer 30 from synchronization circuitry 29 and this is also transmitted by transmitter 21.

The base station 10 receives the synchronization word and the request for channel grant and, by measuring the delay

between the received synchronization word and its own reference, the base station is able to calculate the propagation delay between the antennas 14 and 40.

When the base station 10 is prepared to grant a channel to the mobile radio 11, a channel grant command is input to the multiplexer 16, together with a timing advance command from timing advance circuitry 17. This timing advance command is directed solely to the mobile radio 11 by means of an identification number. The timing advance command is received at receiver 20, demultiplexed at demultiplexer 22 and passed to timing advance circuitry 27. The mobile radio 11 is now ready to transmit speech. Speech which is input at the microphone 32 and coded in coder 31 is multiplexed onto the channel by multiplexer 30 in the appropriate time slot, again with a synchronization word from synchronization circuitry 29. The timing of transmission of this packet of coded speech is controlled by timing control 28 and is dependent on the timing advance from circuitry 27. The timing control 28 advances or retards the transmission so that, when the time slot is received at the base station 10, is accurately synchronized vis-a-vis other time slots arriving from other mobile radios.

The above operation is expected to be satisfactory for short calls which are typical in the private mobile radio environment. A single timing advance command from the base station 10 to the mobile radio 11 at the start of transmission is sufficient to establish the timing for a short call where the mobile radio is travelling relatively slowly.

The mobile radio 11 may be a member of a group. In a trunking system, a channel is generally allocated to a group of radios, all of which switch to receive mode and one of which transmits at a given time. While the channel is considered to be allocated to that group, any member of that group should be able to transmit immediately.

The case should now be considered where the mobile radio 11 has not requested a channel for some considerable time (e.g. five minutes) the mobile radio 11 may wish to immediately respond to a signal received from the base

station. The mobile radio 11 does not need to request a channel, but has not made a recent transmission with which to establish timing.

As is described in greater detail below the operation in these circumstances is as follows.

A timing advance command has been stored in timing advance circuitry 27 from the last occurrence of the mobile radio 11 requesting a channel. In the meantime, the mobile radio receiver 20 has been receiving signals from the base station 10, which may be signals specific to the group to which the mobile radio 11 is allocated or they may be control channel signals or other signals. These are received in circuitry 20 and are not necessarily demultiplexed by demultiplexer 22.

Doppler shift measurement circuitry 26 measures the Doppler shift of the carrier received in receiver circuitry 20. This information tells the mobile radio 11 its speed and motion relative to base station 10. Timing advance circuitry 27 integrates this speed continuously. This enables timing advance circuitry 27 to monitor its relative distance from the base station 10 and to update the timing advance value stored from previous communication with the base station. Thus, when the mobile radio 11 wishes to transmit, it immediately uses the updated value to transmit encoded speech in a time slot.

On receipt of this transmission at base station 10, base station 10 can measure the timing from mobile radio 11 and transmit a new timing advance command on a control channel.

As well as measuring the Doppler shift in circuitry 26, mobile radio 11 can measure the receive signal strength indicator in RSSI circuitry 25 and average this receive strength over time. Averaging is necessary because signal strength is a poor indicator of distance at a given time. Timing advance circuitry 27 can translate the signal strength information into a distance measurement and use this in combination with the Doppler shift measurement and integration to update the timing advance value.

RSSI information can be used on its own, instead of Doppler shift information.

Referring now to Fig. 2, a flow diagram is shown of steps performed by timing advance circuitry 27 and associated control circuitry in the mobile radio 11.

In step 100, timing advance information is acquired from timing advance circuitry 17 in base station 10, as described above. In step 101, the TDM timing reference is adjusted in timing control 28. In step 102, a timer (X) is set to zero. In step 103, the Doppler spread on the base station's transmissions is measured by Doppler shift measurement circuitry 26 and integrated and from this an adjustment of the timing required is computed. As alternatives to step 103 there are steps 104 and 105, which are described below. In step 106, the timer X is compared with a time-out time T. Provided the time-out time is not exceeded, transmission is possible at step 107 within a predefined timing tolerance (t). At this point, the mobile radio can transmit at will.

If in step 106 time T is exceeded, the process passes to step 108, where an access to the control channel is required prior to the next transmission. Such an access causes the base station 10 to transmit new timing advance data. The process returns to step 100.

As an alternative to step 108, the mobile radio can, in step 109, simply transmit in one frame only of the next time slot and wait for timing advance data from the base station 10 in response to such a transmission and subsequently compute the timing error. The transmission on one frame only of the next time slot is described below.

Referring again to Fig. 2, step 104 represents monitoring the speed of the vehicle in which the mobile unit is travelling and using this information to set the time-out time T. Thus, if the vehicle is travelling at speed, the previously received timing advance value becomes obsolete more quickly and an early request must be made to the base station for a new timing advance value. Conversely, if the vehicle is relatively stationary, the existing timing advance value can be used for a longer period of time, thereby avoiding unnecessary exchanges on the control channel.

Referring to box 105, this step represents a fixed time-out value T which is set based on the "worst case" scenario

of the vehicle travelling a maximum speed in a direction radically away from the base station.

Either one of steps 104 and 105 can be used in conjunction with the feature of step 103.

To summarize the above explanation, the invention, at least in its preferred embodiment, arranges for the mobile to establish its range on the signalling channel on registration on the system. This information, and the time it was determined, is then held in memory. If no radio channel access occurs within the next T seconds, where T is a function of the timing accuracy needed and a maximum vehicle speed such that:

$$t = \frac{T \times V_{max}}{c} \text{ seconds}$$

where t = timing accuracy in seconds

V_{max} = max. mobile speed in m/sec

c = speed of light in m/sec

Then the mobile unit control processor (not shown) initiates an up-date of its range by accessing the signalling channel with an appropriate access word designated for this purpose. For a maximum vehicle speed V_{max} of say 200KM/hr (55.6m/s), and a window tolerance t of say 60µs seconds the time interval would be approximately 5.5 minutes. Recognising that it is unlikely for the vehicle to be travelling at this speed radially away from the base site for a sustained duration, and up-date period of approximately 10 minutes is adequate in practice. In fact, by employing the Doppler spread information available by processing the near continuous base transmissions on the signalling channel, it is possible to have a much more refined estimate of the vehicle speed and this is employed to calculate when the mobile might have exceeded the range in its memory by more than the window tolerance. With this knowledge, the average period between no-access up-dates can be so low as to be negligible as an extra traffic burden on the signalling channel. In the event of an actual voice transmission initiation occurring, this is used to update the memory

directly. The staggering arrangement in typical TDM systems facilitates this monitoring of the mobile's own next transmission. The mobile transmits and monitors its own transmissions (outbound) and recovers exact corrected timing information in the next control transmission from the base station.

It will be appreciated that instead of monitoring vehicle speed, or Doppler spread, other methods can be used to estimate or calculate the relative distance between the base station and the mobile radio. For example, in a system such as TETRA, there is a regular broadcast transmission in the first block of the control frame which occurs once per second and includes a known sequence of symbols, e.g. a synchronization word. On receiving a timing advance instruction from the base station, the mobile radio has the opportunity to measure the relative time delay between its now corrected transmit timing and the time it receives the regular broadcast transmission. Now at appropriate intervals the mobile radio monitors the broadcast message, measures the relative time delay and decides whether an adjustment in transmit timing is required (and either makes that adjustment locally or requests a new timing advance signal).

As a further alternative, a global positioning system receiver can be used to provide exact position indications.

Referring now to Fig. 3, a known arrangement for encoding speech and inserting encoded speech into a time slot is shown, taking the TETRA system as an example.

Speech from the microphone 32 is encoded by the speech coder 31 in frames. A speech frame is typically 30 milliseconds and two speech frames (60 milliseconds of speech) can be encoded into a time slot of duration 14.167 milliseconds. The encoded speech from speech coder 31 is multiplexed by multiplexer 30 together with synchronisation signalling from synchronization circuitry 29 and/or other signalling and transmitted on the time slot. At each end of the time slot there is a guard time which is allowed for ramp-up and ramp-down of the amplifier.

In accordance with one aspect of the present invention, when a mobile radio wishes to transmit, but has not recently

received a timing advance value from its base station, the first burst that it transmits is a shortened transmission burst, such as in shown in Fig. 4. Only one frame of speech (30 milliseconds) is encoded by speech coder 31 and a transmission burst is compiled by multiplexer 30 from this reduced speech data. The resulting transmission burst is therefore shorter than the time slot into which it is allocated and additional guard time 210 and 211 is generated at the start and end of the time slot. The reduced transmission burst is timed by the timing control 28 to fall approximately in the centre of the time slot. The time slot is calculated by the timing control circuitry 28 from synchronization information from synchronization circuitry 29 and the previous (outdated) timing advance information 27. Thus, the additional guard time 210, 211 allows for inaccuracies in the timing advance information. When the reduced transmission burst is received by the base station, the base station transmits a new timing advance value and the mobile 11 is then in a position to transmit the full allocation of speech (2 speech frames) in each subsequent time slot, as shown in Fig. 3.

In this manner, speech can be transmitted from the outset. Two advantages arise from this arrangement. First, the reduced delay in transmitting speech (50 milliseconds) is considered to be just within the range of perception of a user. More significantly, use is made of a time slot that would otherwise be wasted.

Claims

1. A communications system comprising a base station and a mobile radio arranged for communication over a TDMA channel having a predetermined frame reference, wherein the base station comprises means for receiving signals from the mobile radio, means for measuring the timing of those signals relative to said frame reference and means for transmitting a timing advance signal to the mobile radio and wherein the mobile radio comprises means for receiving the timing advance signal, means for transmitting to the base station with controlled timing and means for adjusting the timing of transmitting in response to the received timing advance signal, characterized in that

the mobile radio is arranged to estimate change of distance from the base station since last receiving a timing advance signal and locally to decide whether transmit timing adjustment is required.

2. A system according to claim 1 wherein the mobile radio is arranged to request a new timing advance signal at a time which is dependent on said estimated change of distance.

3. A system according to claim 1 or 2, wherein the mobile radio comprises means for independently adjusting the timing of subsequent transmissions when it decides that timing adjustment is required.

4. A system according to claim 1, 2 or 3 wherein the means for estimating change of distance comprise Doppler shift measurement means for estimating speed relative to the base station and integrator means for integrating said speed over time.

5. A system according to any one of claims 1 to 4 wherein the base station comprises means for transmitting at a predetermined power known to the mobile radio and wherein the means for estimating change of distance comprises means for

measuring the attenuation from said known power of transmissions received from the base station.

6. A system according to claim 5 wherein the means for measuring the attenuation of the known power further comprise means for averaging said power to reduce the effect of fading.

7. A system according to any one of the preceding claims wherein the means for estimating change of distance comprise means at the mobile radio for receiving regular signals from the base station and measuring the relative times of receipt of said signals.

8. A mobile radio of a communications system comprising a base station and a mobile radio arranged for communication over a TDMA channel comprising means for receiving a timing advance signal from a base station, means for sending transmissions to the base station with controlled timing and means for adjusting the timing of transmissions in response to the received timing advance signal, characterized in that the mobile radio is arranged to estimate change of distance from the base station since last receiving a timing advance signal and to locally decide whether transmit timing adjustment is required.

9. A mobile radio according to claim 8 arranged to request a new timing advance signal at a time which is dependent on said estimated change of distance.

10. A mobile radio according to claim 8 or 9, further comprising means for independently adjusting the timing of subsequent transmissions when the radio decides that timing adjustment is required.

11. A communications system comprising a base station and a mobile radio arranged for communication over a TDMA channel having a predetermined frame reference, said channel being divided into time slots, wherein the base station comprises

means for receiving signals from the mobile radio, means for measuring the timing of those signals relative to said frame reference and means for transmitting a timing advance signal to the mobile radio and wherein the mobile radio comprises means for receiving the timing advance signal, means for transmitting traffic to the base station in bursts of a predetermined duration and means for adjusting the timing of transmitting of its bursts in response to the timing advance signal, characterized in that

the mobile radio comprises means for transmitting a burst of reduced duration, less than said predetermined duration, and means for receiving a timing advance signal in response to transmission of said burst of reduced duration so as to enable commencement of transmission of bursts of said predetermined duration with adjusted timing.

12. A communications system according to claim 11, wherein said mobile radio comprises a speech coder for coding speech in frames of encoded speech and means for compiling said bursts from said frames of encoded speech where each burst of said predetermined duration comprises N frames of encoded speech and said burst of reduced duration comprises M frames of encoded speech, where N and M are non-zero integers and M is less than N.

13. A communications system according to claim 11, where N=2 and M=1.

14. A mobile radio of a communications system comprising a base station and a mobile radio arranged for communication over a TDMA channel, said channel being divided into time slots, the mobile radio comprising means for receiving a timing advance signal from a base station, means for transmitting traffic to the base station in bursts of a predetermined duration and means for adjusting the timing of transmission of its bursts in response to the timing advance signal, characterized by means for transmitting a burst of reduced duration, less than said predetermined duration, and means for receiving a timing advance signal in response to

transmission of said burst of reduced duration so as to enable commencement of transmission of bursts of said predetermined duration with adjusted timing

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report) -16-

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Relevant Technical fields

(i) UK Cl (Edition L) H4L (LDC)
H4P (PPF)

(ii) Int Cl (Edition 5) H04B 7/212 7/26

Databases (see over)

(i) UK Patent Office

(ii) ON-LINE: WPI

Search Examiner

N W HALL

Date of Search

10 MAY 1993

Documents considered relevant following a search in respect of claims 1-10

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
A	US 4252999	(ACAMPORA) see particularly Claim 3	
A	US 4653049	(SHINMYO) whole document	

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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